DMIC

JPRS: 26,959

TT: 64-51215

19 October 1964

Ok

CARBURIZING AND HEAT TREATABLE STEELS DI-2, DI-3, DI-3A (EP-176) AND DI-4

by M. F. Alekseyenko, et al

- USSR -

60997

U. S. DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
JOINT PUBLICATIONS RESEARCH SERVICE
Building Tempo E
East Adams Drive, 4th & 6th Streets, S.W.
Washington, D. C. 20443

Price: $1.00

I-i

F O R E W O R D

This publication was prepared under contract for the Joint Publications Research Service as a translation or foreign-language research service to the various federal government departments.

The contents of this material in no way represent the policies, views or attitudes of the U. S. Government or of the parties to any distribution arrangement.

PROCUREMENT OF JPRS REPORTS

All JPRS reports may be ordered from the Office of Technical Services. Reports published prior to 1 February 1963 can be provided, for the most part, only in photocopy (xerox). Those published after 1 February 1963 will be provided in printed form.

Details on special subscription arrangements for any JPRS report will be provided upon request.

No cumulative subject index or catalog of all JPRS reports has been compiled.

All current JPRS reports are listed in the Monthly Catalog of U. S. Government Publications, available on subscription at $4.50 per year ($6.00 foreign), including an annual index, from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

All current JPRS reports are cataloged and subject-indexed in Technical Translations, published semimonthly by the Office of Technical Services, and also available on subscription ($12.00 per year domestic, $16.00 foreign) from the Superintendent of Documents. Semiannual indexes to Technical Translations are available at additional cost.

JPRS: 26,959

CARBURIZING AND HEAT TREATABLE STEELS DI-2, DI-3, DI-3A (EP-176) AND DI-4

[Following is a translation of an article in the Russian-language journal Stal' (Steel) by M. F. Alekseyenko, G. I. Vasilenko, B. S. Natapov, G. N. Orekhov, M. V. Pridantsev and V. P. Frantsov, Moscow, No 7, July 1964, pages 642-645.]

For replacing high alloy steels 18Kh2N4VA and 20Kh2N4A low-nickel steels DI-2 (18KhGSN2MVA) and DI-4 (18KhGSN2MA) have been developed, and steel DI-3A or EP-176 (14KhGSN2MA) is being designed for replacement of steels 12KhN3A and 12Kh2N4A. According to the physical and mechanical properties of the new steels, they are as good as the steels they are replacing and the consumption of nickel in their production is on the average 20-25 kg/t less.

Up to now, for heavy-loaded parts of responsible machine building they use high-alloy steels 12KhN3A, 12Kh2N4A, 12Kh2H4VA and 20Kh2N4A which are characterized by a high content of deficient nickel, a significant quantity of retained austenite held in the layer after chemical heat treatment, and a low thermal stability of the carburized layer.

The authors of this article [See Note] created a group of low-nickel carburizing steels which by their physical and mechanical properties are on par with high-nickel steels and possess optimum properties of the carburized layer in parts.

[Note: In this work participated V. Ye. Pronin, G. Kh. Gabuyev, Yu. P. Shamil', T. M. Babkov, L. I. Yefremova, I. P. Banas, M. S. Kunin, G. V. Kulygin, Ye. L. Bushmanova, L. G. Kozyrev, S. Z. Yudovich, P. I. Sklyarov, D. D. Tishchenkvo, V. M. Doronin, and T. V. Levchenko.]

In the development of new grades of steels use was made of scrap Cr-Ni-Mo steels available in the country in a large quantity, and "uniformity" of chemical composition for facilitating metallurgical production.

Special attention was given to the correct proportion of elements, promoting carburization and preventing it. For this purpose, on specially melted low-carbon alloys, the joint influence of the basic elements (Cr, Mn, Si, Ni, W, Mo, V) was investigated on the concentration of carbon in the layer. Here it was revealed that the biggest influence is rendered by chromium and silicon, and the limits of content of the basic elements in new steels in % established (numerator -- upper limit, denominator -- lower) (the abbreviation DI signifies to p. 5 "Dneprospetsstal' research;" the permissible content of vanadium in all steels 0.06% (max), sulfur and phosphorus -- 0.03% (max):

	C	Si	Mn	Cr	Ni	W	Mo
DI-2 (18KhGSN2VMA)	$\frac{0,14}{0,21}$	$\frac{0,35}{0,65}$	$\frac{0,65}{0,95}$	$\frac{1,1}{1,6}$	$\frac{1,8}{2,4}$	$\frac{0,5}{0,8}$	$\frac{0,20}{0,30}$
DI-3 (14GSN2A)	$\frac{0,11}{0,17}$	$\frac{0,35}{0,65}$	$\frac{0,65}{0,95}$	$\frac{1,0}{1,6}$	$\frac{1,4}{2,0}$	—	—
DI-3A (14KhGSN2MA)	$\frac{0,11}{0,17}$	$\frac{0,35}{0,65}$	$\frac{0,65}{0,95}$	$\frac{1,3}{1,7}$	$\frac{1,4}{2,0}$	—	$\frac{0,20}{0,30}$
DI-4 (18KhGSN2MA)	$\frac{0,15}{0,22}$	$\frac{0,35}{0,65}$	$\frac{0,65}{0,95}$	$\frac{1,0}{1,5}$	$\frac{1,4}{2,0}$		$\frac{0,20}{0,30}$

Steel DI-3, not containing molybdenum, is recommended only to replace steel 12KhN3A. Molybdenum in steel DI-3A (also designated as EP-176) can completely or partially replace tungsten from the calculation Mo:W = 1:3.

At the Dneprospetsstal' Plant, according to the production technology standard high-alloy carburized steels several heats of the new steels were melted and rolled into various shapes for a thorough investigation of their physical and mechanical properties.

Critical points were determined on a Shevenar dilatometer (samples with a diameter of 3 mm and length of 50 mm). Position of the Ms point was calculated by the formula of A. A. Popov [1].

Transformation of austenite during cooling was investigated on a torque magnetometer of N. S. Akulova. Stability of austenite in steels DI-3A and DI-4 (EP-176) was obtained the same as in steels 12KhN3A and 12Kh2N4A, but in steel DI-2 -- somewhat less than in steel 18Kh2N4VA.

The influence of quench temperature in the interval 800-950°C on mechanical properties of the steels was obtained as follows (numerators -- quenching in oil, denominators -- in air; in both cases -- tempering was done at 180°C, [for those samples which cracked upon water quenching, only oil quench temperatures are given], d_B -- diameter of Brinell impression):

Steel	t, °C	σ_B кг/мм²	δ %	ψ %	$a_к$ кгм/см²	d_B мм
DI-2	800	144,4	14,3	60,6	12,7	3,05
	840	144,0 / 123,0	13,5 / 15,5	60,7 / 60,0	11,9 / 17,0	3,05 / 3,30
	860	145,0 / 121,0	14,2 / 16,6	60,7 / 60,9	12,0 / 17,5	3,05 / 3,35
	900	140,3 / 122,4	11,2 / 16,0	59,6 / 60,5	12,0 / 17,8	3,05 / 3,30
DI-3	800	112,7	15,5	60,5	11,0	3,5
	825	116,3	14,5	61,0	11,7	3,5
	850	115,3	16,0	63,0	12,4	3,4
	900	114,7	14,5	59,0	13,4	3,4
	950	114,3	15,0	59,0	12,2	3,5

Both these steels had high strength and ductility in the investigated interval of temperatures. The optimum temperature of quenching for them may be considered to be 820-860°C. The average values of properties after quenching from the optimum temperature (for DI-2 from 860 ± 10°C, and for all other steels -- from 840 ± 10°C) in oil and low temper (at 180°C) were very high (for steel DI-2 and DI-4 the properties of separate heats, somewhat differing in chemical composition are given).

Steel	σ_B кг/мм²	$\sigma_{0,2}$ кг/мм²	δ %	ψ %	$a_к$ кгм/см²	d_B мм
DI-2	140,0	122,0	15,0	55,0	11,0	3,0
	128,5	118,3	14,4	61,2	16,7	3,12
	147,0	—	12,5	58,5	12,0	3,05
DI-3	109,0	95,0	15,0	62,0	15,0	3,3
	130,0	105,6	12,5	64,0	14,5	3,15
DI-4	132,0	120,4	14,0	53,6	13,8	3,10
	140,5	130,0	10,0	50,5	9,9	—

The influence of tempering temperature t_T on the mechanical properties steel DI-2 was checked after quenching in oil from 840-860°C; cooling after tempering at 400°C was conducted in air, and at higher temperatures -- in water. The obtained results make it possible to recommend high tempering of steel DI-2 in the interval 530-600°C.

t_T °C	σ_B кг/мм²	δ %	ψ %	$a_к$ кгм/см²	d_B мм
200	146,0	12,5	59,0	12,2	3,0
300	143,7	15,6	60,0	11,1	3,05
400	153,0	13,4	60,0	9,6	3,10
500	114,0	16,9	62,0	16,6	3,30
580	114,5	16,8	66,7	19,25	3,35
600	103,5	15,0	69,5	23,4	3,50
650	90,0	19,3	74,0	23,8	3,70
700	83,5	22,0	69,0	22,0	3,90

The hardenability of the steel was determined on slices cut from the middle of heat treated blanks of different diameters. The

investigated melts as to carbon and alloying elements content were made basically on the lower limit of technical conditions. It can be recommended to use steel DI-2 for quenching in air in rounds up to 80 mm in diameter and for quenching in oil -- up to 150-200 mm. Steels DI-3A and DI-4 is recommended for cross sections up to 80 mm, and steel DI-3 -- to 40 mm.

Steel DI-2 in 100-mm rounds and DI-3A (EP-176) in 75-mm rounds maintain high mechanical properties over the entire cross section (quenching from 850-870°C in oil, temper at 180-170°C, I -- center, II -- middle of radius, III -- surface).

	d, mm	Point of cutting samples from ingots	σ_B кг/мм²	$\sigma_{0,2}$ кг/мм²	δ %	ψ %	a_K кгм/см²	d_B мм
DI-2	20	I	136,0	118,3	12,3	58,5	11,3	3,05
	30	II	148,2	136,0	14,0	57,9	10,75	3,05
	100	III	120,8	104,0	14,0	51,2	14,0	3,15
		II	116,0	98,3	15,5	59,9	14,7	3,25
		I	117,5	96,0	14,0	57,9	10,75	3,20
DI-3A (EP-176)	75	III	122,0	94,0	16,3	62,4	14,0	3,4
		I	108,0	82,8	15,8	63,0	15,6	3,4

The influence of prolonged high-temperature heating was checked on standard fracture and impact samples after blank carburizing and blank nitriding. It turned out to be insignificant. The new steels are distinguished by a fine grain, the size which during heating to 1,000°C remains within the limits of 7-6 points [on the grain index].

As to impact strength the new steels are on par with high-alloy steels -- and even at -196°C their impact strength is adequate, kgm/cm (in parentheses is shown R_c hardness; steels DI were quenched from 850°C in oil, high-nickel steels -- from 820 and 860°C; tempering in all cases was done at 180°C).

Steel (R_c)	Testing temperatures, °C +20	-40	-70	-82	-196
DI-2 (43)	14.6	12.8	11.5	11.3	2.9
	11.0	9.8	9.1	8.2	2.5
DI-3 (36)	12.0	9.5	8.7	8.0	1.9
DI-3A (-) (EP-176) . .	11.4	10.8	8.9	-	4.0
DI-4 (40)	12.5	10.5	9.5	-	2.7
12KhN3A (36)	11.3	11.1	8.5	-	2.2
12Kh2N4A (39)	10.0	8.5	8.0	-	2.9
18Kh2N4VA (40)	11.5	10.0	8.7	-	4.0

Notch sensitivity of the steels was checked on samples having ring cuts without torsion (A) and with torsion of 4^o and 8^o (B and C) after heat treatment under the same conditions. The ratios of obtained ultimate strengths to their values for smooth samples testify to the low notch sensitivity of the new steels (for samples of type A from steels 18Kh2N4VA and 12KhN3A this ratio, according to earlier published data [2], was, respectively, 1.32 and 1.13, and for steel DI-3A -- 1.47-1.50):

	A	B	C
DI-2	1.36	1.17	0.81
	1.36	1.15	0.97

	A	B	C
DI-3	1.35	1.18	0.76
	1.26	1.19	0.67
	-	1.18	0.81

For carburized parts, operating under conditions of variable loading, an important property is fatigue strength; it was determined on an NU machine for 10^7 cycles at a variable bend for diverse variants of heat treatment (I -- quenched from 850-860°C in oil and tempered at 180°C; II -- blank carburizing at 920°C for 12 hours, quenched from 850°C in air, cold treatment (at -70°C) for 2 hours and tempered at 170°C; II -- the same, but quenched in oil; III -- carburized at 920°C for 8 hours, quenched from 850°C in oil and tempered at 160°C for 2 hours). The fatigue strength for smooth (σ_{-1}) and notched (σ_{-1}^{N}) samples was obtained as follows (for steel DI-3A fatigued was determined on selector samples). ES

Steel	DI-2		18Kh2N4VA	DI-3A	DI-3A		DI-4A
Treatment . . .	I	II	II	II^1	II^1	I	III
σ_{-1}, kg/mm^2 . .	61	60	56	54	52-63	52.6	88
σ_{-1}^{N}, kg/mm^2 . .	34	29	29	26	32-42	31.8	43.5
$\sigma_{-1}/\sigma_{-1}^{N}$	1.80	2.07	1.93	2.08	1.66-1.5	1.65	2.05

ES

Thus, the new economic steels have a high fatigue strength, equal to that of high-nickel steels. Carburizing significantly increases the fatigue strength which is evident for steel DI-4.

It is known that a decided influence on efficiency of a part is rendered by the carburized layer: its saturation with carbon, uniformity of distribution of carbon in the layer, and depth of layer. Up to now, the best in this respect were considered to be high-alloy steels 12KhN3A, 12Kh2N4A and 18Kh2N4VA. The carburized layer of the new grades of steels was investigated in parallel with the carburized layer of these high-alloy and high-nickel steels after different variants of chemical and heat treatment, carried out at a number of plants.

Sublayer chemical analysis showed that saturation of the layer with carbon and its depth in the new steels are obtained the same as in high-alloy steels, but with less retained austenite.

Influence of Tempering Temperature on Hardness of Carburized Layer R_c
(samples with diameter of 25 mm, height of 6 mm)

Steel	Treatment, C*1	- *2	Tempering temperature °C (2 hours)									
			160	200	250	300	350	400	450	500	550	600
DI-3A (EP-176)	A	63	62	61	60	58	56	-	-	-	-	-
DI-2		64	60-61	59-60	58-59	57-58	56	52-54	49-50	47-48	46-47	43
DI-3		65	61-62	60	58-59	57	55	51-52	49	45	-	38
	B	64	60-61	59-61	60	57-59	57-58	53-55	50-52	48-50	-	-
DI-4		64	60-61	60	58-59	58	56	53	50	47-48	44	39
18Kh2N4VA		59-60	55	55	55	54-55	53-54	50-51	50	47	45	43
12KhN3A		62-63	60	58	57	51-52	-	-	-	-	-	-
12Kh2N4A	C	64	60	58-59	57	55-56	53	50	48-49	42-43	-	36
20Kh2N4A		64	60-61	60-61	58-60	55-56	53-54	49-51	47-48	42-43	37-38	31-32

*1 Quenching from 850°C in oil and carburizing at 920°C for 10 hours, in solid carburizer (30% fresh +70% worked); B -- carburized under same conditions and quenched from 840°C in oil; C -- the same, but from 780°C.

*2 Hardness after quenching, R_c.

An improvement of the new steels is the increased temperature of softening during tempering (table) which allows to recommend them for parts operating at temperatures up to 250-300°C. The new economic steel can also be nitrided.

Thus, steels DI-2, DI-3, DI-3A (EP-176) and DI-4 as to physical and mechanical properties of the carburized layer and center can successfully replace high-alloy steels 12KhN3A, 12Kh2N4A, 18Kh2N4VA and 20Kh2N4A, where the content of scarce nickel in them is 2.0-2.5% less.

At present these steels have successfully withstood long-time tests and are being introduced into series production at machine-building plants.

BIBLIOGRAPHY

1. Mes'kin, V. S., Osnovy Legirovaniya Stali (Fundamentals of Alloying Steel), Metallurgizdat, 1959.

2. Alekseyenko, M. F. and Orekhov, G. N., Stal' (Steel), No 6, 1960.

- END -

6368
CSO: 1879-D/PE